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Effect of irrigation management and polymer levels on some hydraulic properties of gypsum soil utilizing a Fixed Sprinkler Irrigation System in a Desert Environment

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ABSTRACT

A field experiment was conducted in a sandy clay loam soil during the spring season (2023) in the Habbaniyah District, specifically in the Khalidiya District of Anbar Governorate, located on the right side of the Nazim Habbaniyah project. The objective was to investigate the effect of irrigation management and Different levels of polymer addition on the properties of gypsum soil. Irrigation was applied when 40%, 50%, and 60% of the available water was depleted, while polymer was incorporated at rates of 0, 0.001, and 0.002 by soil weight. The experimental parameters were organized using a factorial design based on a randomized complete block design (RCBD). Potato tubers of the Burin variety were planted, and Class A evaporation pans were utilized for irrigation scheduling**.**The results indicated a reduction in the infiltration rate following the conclusion of the season across all treatments when compared to the before planting values. The peak rate recorded was 9.25 cm h^{-1} under the 40% depletion treatment with an addition of 0.002, while the lowest rate was 5.81 cm h^{-1} observed in the 60% depletion treatment without any addition. Additionally, the very best coefficient of determination (R2) between cumulative infiltration and time turned into 0.9982 for the forty% depletion remedy with the 0.002 addition, while the lowest coefficient was 0.9938 for the 60% depletion treatment with none addition.

تأثير ادارة الري ومستويات البوليمر في بعض الخصائص الهيدروليكية لتربة جبسية تحت نظام الري بالرش الثابت في البيئة الصحراوية

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الخلاصة
أجريت تجربة حقلية في تربة مزيجة طينية رملية Sandy Clay loam خلال الموسم الربيعي (2023) ، في ناحية الحبانية - قضاء الخالدية - محافظة الانبار غرب العراق الواقعة على الجانب الايمن من مشروع ناظم الحبانية, لدراسة تأثير إدارة الري واضافة مستويات البوليمر في بغض خصائص غيض التربة الجبسية. تم الارواء عند استنزاف 40, 50 و60 % من الماء الجاهز, واضيف البوليمر بمستوى 0 و 0.001 و 0.002 من وزن التربة, وزعت معاملات الدراسة بتجربة عاملية وفق تصميم القطّاعات الكاملة التعشية (RCBD). زرعت درنات البطاطا صنف بورين و استخدم حوض التبخر الامريكي صنف A في توقيت الري. بينت النتائج انخفاض معدل الغيض بعد نهاية الموسم ولكافة المعاملات مقارنة مع قيمه قبل الزراعة اذ بلغت اعلى قيمة 9.25 سم ساعة$^{-1}$ عند معاملة استنفاد 40% والاضافة 0.002, واقل قيمة 5.81 سم ساعة$^{-1}$ عند معاملة استنفاد 60% مع معاملة بدون اضافة. بينما اعلى معامل تحديد R^2 بين الغيض التراكمي والزمن بلغ 0.9982 عند معاملة استنفاد 40% والاضافة 0.002 واقل قيمة 0.9938 عند استنفاد 60% وبدون إضافة.
الكلمات المفتاحية: أدارة الري، الترب الجبسية، الخصائص الهيدروليكية

INTRODUCTION

The deficit in water sources constitutes one of the maximum critical and largest challenges dealing with irrigated agriculture within the world with the growth in demand and cultivated place within the world in maximum cases, the quantity of available water isn't enough to cover crop requirements (Khairo, 2024). Lands located in arid and semi-arid areas face demanding situations because of insufficient rainfall and precipitation, necessitating the adoption of irrigated agriculture to meet water desires for sustainable crop manufacturing. This approach aims to increase agricultural land to enhance output in response to the growing world populace, which in turn needs improved irrigation water resources. Therefore, it's far crucial for water customers and researchers to implement strategies that concentrate on the efficient use of irrigation water and ensure its availability for scientifically planned cultivation regions. The powerful management of water resources is critical in these regions, and one effective approach involves regulating the volume of water implemented during irrigation based totally on the soil's absorption capacity and the plant's necessities at diverse increase tiers. This method aims to acquire most efficient productivity even as minimizing water loss, as mentioned through (El-Obeid and El-Shaabani, 2021).

Gypsum is taken into consideration a rock-forming mineral It is also found in soil. In arid and semiarid environments, gypsum can be a basic component of soil (Kamal and Rashid, 2020).Gypsiferous soils are described as soils in which gypsum (CaSO4.2H2O) accumulates, so that it has a great effect on plant growth (Farhan and Muhawish, 2022). Gypsum soils cover areas of land in the central and northern sedimentary plain of Iraq. (Al-Jumaily et al., 2022). Most of these lands be afflicted by a couple of troubles affecting their agricultural productivity (Ismaeal, 2022). Gypsiferous soils are characterized by way of low water retention and nutrients, this depends on the traits of gypsum minerals (Al-Kayssi, 2022). In recent years, numerous chemical compounds have been utilized in agriculture as additives to improve soil water retention.. Among those, Super Absorbent Polymers (SAP) stand out as a They are molecules that have the ability to absorb and retain water.. These polymers possess the particular ability to soak up and hold sizeable quantities of liquid because of their molecular shape, which incorporates carboxylic corporations that facilitate the binding of cations and water. SAP offers numerous benefits for restoring degraded lands, together with increasing the soil's capability to hold water, which lets in plants to thrive for extended durations due to advanced soil shape and moisture retention. Additionally, SAP reduces water consumption by decreasing evaporation rates. It also achieves a higher growth rate compared to the control treatment. They additionally play a position in binding heavy metals, thereby lessening their effect on flowers, and help mitigate salinity consequences. The benefits of the usage of SAP It has benefits to the soil that far outweigh its costs (cheap), (Hartmann et al. 2005). Glab and Kopec (2003) show that the bulk density and total porosity of soil are affected by the method and level of irrigation water addition, as well as the method and speed of wetting. This is due to the movement of fine soil particles resulting from the deterioration of soil aggregates and clumps during water addition and the closing of large pores. This leads to a change in the volume distribution of pore spaces, and consequently, an increase in bulk density.

Hydraulic stress, resulting from the force of water applied to the soil structure, affects the wetting and drying cycles, which are influenced by irrigation levels. This leads to increased soil structural deterioration, clogging of soil pores, and a consequent decrease in saturated water conductivity (Alaoui et al., 2011). Salih (2023) reported that adding 0.4% polymer resulted in the highest stability value for soil aggregates, reaching 54.2%. In contrast, when the polymer concentration was reduced to 0.2%, the stability value decreased to 47.2%,The effect of adding amendments is attributed to their important role in improving soil structure and re-distributing pores by binding particles together, or to the fact that some of the particle surfaces are covered with hydrophobic materials, which creates a large contact angle that prevents water from moving easily and thus prevents the disintegration of soil aggregates (Mandall et al., 2013).

This study was conducted with the aim of effect of soil moisture depletion rates on different infiltration characteristics. The effect of polymer on the coefficient of determination R2 and the basic filtration rate.

MATERIALS AND METHODS

A field experiment was conducted in a sandy loam soil during the spring season in Habbaniyah District, specifically in the Khalidiya District of Anbar Governorate, located in western Iraq. This site is located on the right side of the Nazim Habbaniyah project, approximately 1 km east of the district center.

The soil was morphologically characterized and classified as belonging to the Typic haplo Gypsid group according to the American classification system (USDA, 2010), and it corresponds to the G2143XXW series as proposed by AL-Agidi (1981). The characteristics of the irrigation water were assessed using the techniques recommended by the American Salinity Laboratory. Euphrates water was utilized for irrigating the potato crop, and its chemical characteristics are presented in Table (2).

Table (1): some physical & chemical characteristics of the soil before agriculture.

Characteristic		**Quantity**	**Unit**
Sand		528	
Silt		232	g kg^{-1}
Clay		240	
Sand clay loam		Sand clay loam	
bulk density		1.28	Mg m^{-3}
Saturated water conductivity		7.28	Cm h^{-1}
Cumulative Infiltration		44.39	Cm
Basic Infiltration rate		9.92	Cm h^{-1}
Waited moisture for soil in tension(kilopascal)	33	24.74	%
	1500	9.56	
$CaSO_4.2H_2O$		58.9	
$CaCO_3$		175.00	g kg^{-1}
(pH)		8.1	———
(EC)		3.5	dS m^{-1}
Ca^{2+}		14.80	
Mg^{2+}		9.50	
Na^{+}		7.24	
K^{+}		0.95	Meq L^{-1}
SO_4^{2-}		2.50	
CO_3^{2-}		Nill	
Cl^{-}		14.00	

Table (2): Chemical characteristics for irrigated water

EC* **dS.m^{-1}**	**pH***	(meq L^{-1})								**$NO_3^{=}$ ppm**	**SAR**	Class
		Ca^{+2}	**Mg^{+2}**	**Na^{+}**	**K^{+}**	**Cl^{-}**	**SO_4^{-2}**	**HCO_3^{-}**	**$CO_3^{=}$**			
0.98	7.4	4.1	2.89	2	0.14	4.0	3.5	2.0	0.0	2.10	1.15	C_3S_1

The experiment involved an investigation into the effect of three different soil moisture depletion ratios 40%, 50%, and 60% of available water alongside three Different levels of polymer, specifically 0.00, 0.001, and 0.002 of soil weight**.**

A plot of land was selected from an area served by a fixed sprinkler irrigation system measuring 152.5 meters in length and 60 meters in width. This area was then divided into three equal sections, each measuring 152.5 meters by 18 meters, with a 2 meter buffer zone between them. Within each section, three irrigation depletion ratios were arranged

perpendicular to the prevailing wind direction to serve as the main panels. Each depletion ratio consisted of three repeaters, and polymer coefficients were incorporated into each repeater. The tillage process involved creating a flat area 15 meters long and 0.75 meters wide using a rototiller, followed by loosening the soil. Additionally, a 1.5 meter space between the polymer treatments, which included three levels with three replicates, leaving a 2 meter space.
Potato tubers of the Burin variety were placed in each hole, with the application of Revanol SL (a bacterial fungicide) at a rate of 100 ml per 100 liters of water to safeguard against fungal infections until harvest. The spacing between rows was set at 0.20 meters, accommodating 75 plants per row, resulting in a total of 2025 plants**.**
The study treatment were allocated based on a factorial experiment following the Randomized Complete Block Design (RCBD) with three replications. The moisture depletion ratios were assigned randomly to the coefficients, and the coefficients for the addition method were also distributed randomly. Consequently, the total number of experimental units was calculated as 3×3×3, resulting in 27 units. Calibration irrigation was implemented and continued until 40% of the available water was depleted. After 87% emergence was complete, irrigation was performed using 40%, 50%, and 60% of the available water consumed for each treatment.

Calculation the infiltration rates

The assessment of infiltration rates for various experimental coefficients was conducted using double rings, with the outer ring measuring 0.6 meters in diameter and the inner ring measuring 0.3 meters. A water source, consisting of a tank with a float, was connected to the outer ring. A measuring tape was installed to measure the depth of the water within the soil, with measurements taken at periods of 1, 5, 10, 20, 30, 60, 120, 180, 240, and 300 minutes. The depth of the turbid water was recorded at each interval, and the infiltration parameters were calculated accordingly.

1. Cumulative infiltration: The relationship between cumulative infiltration and time is characterized by the equation introduced by Philip (1957), which is based on the principles of water movement through homogeneous porous media.

$$I = St^{0.5} + At \quad \ldots\ldots(1)$$

Whereas:-

I: infiltration (cm h^{-1}).

S : sorptivity factor that depends on the structural potential of the soil and its volumetric moisture (ϴ) Its units (cm $min^{-0.5}$).A: constant depends on the water conductivity of the soil (K) and its volumetric moisture (ϴ).

t: Time (min).

The equation constants are calculated by the least Squares method.

2- Infiltration rate: - Calculated by differentiation of equation 1 as follows:

$$dI/dt = i = \frac{1}{2} St^{-1/2} + A \quad \ldots\ldots(2)$$

The results were analyzed with Genstat v.12.1 and the averages were compared according to the least significant difference test (LSD) at a probability level of 0.05.

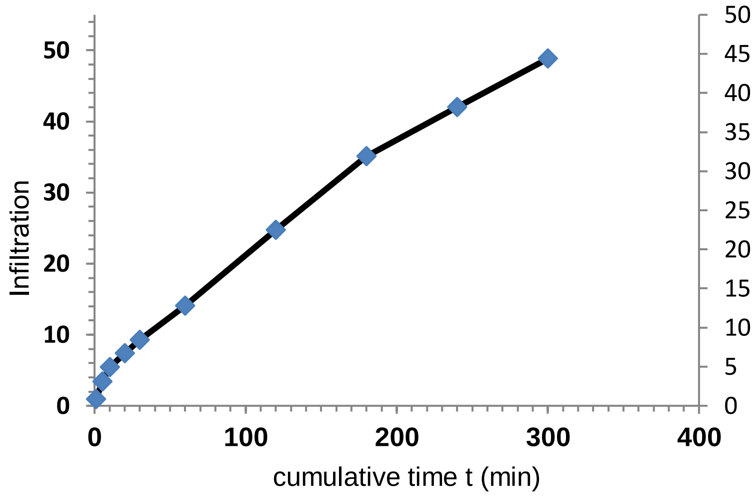

Figure (1) shows the relationship between cumulative infiltration and measurement time.

RESULT AND DISCUSSION

Figures 2, 3, and 4 shows the effect of the Experiment transactions on cumulative infiltration. The coefficient of Determination (R^2) ranged from 0.9938 to 0.9941 for the coefficients without components, at the same time as it various from 0.9936 to 0.9943 for the addition of 0.001 polymer, and reached between 0.9946 and 0.9982 for the addition of 0.002 polymer. For any depletion ratio, the soil absorption (S) become recorded between 0.0754 and 0.0979 cm min^{-1} for the coefficients without components, increasing to quite a number 0.0974 to 0.1393 cm min^{-1} for the 0.001 polymer addition, and among 0.1015 and 0.1336 cm min^{-1} for the 0.002 polymer addition.The determination factor and absorption factor (S) before to planting were approximately 0.9949 and 0.1548 cm min^{-1}, respectively. It was observed that cumulative infiltration values declined following the application of the study treatment after planting compared to their pre-planting values, with a decrease of 4.48% when draining 40% with the 0.002 polymer addition, and a significant reduction of 39.85% when draining 60% without any additives. This decline in cumulative infiltration values after planting may be attributed to the increased bulk density of the soil resulting from agricultural and irrigation operations, which reduces the percentage of pore spaces, particularly larger ones, thereby diminishing the flow area , Also, increasing the bulk density results in a lower in large pores and an increase in medium and small pores, which affects the hydraulic conductivity. This is constant with what was found by using (Fuentes et al., 2004; Horn and Smucker, 2005). Therefore, bulk density affects the pore diameter and distribution, and therefore the hydraulic homes of the soil.

As shown in the same figures, the effect of depletion rates on the cumulative infiltration values after planting, with a notable decrease observed as soil moisture depletion rates increase. The highest cumulative infiltration values recorded were approximately 34.90, 38.70, and 42.40 cm when 40% of the available water was drained. In contrast, when 50% of the available water was drained, the values dropped to 30.80, 33.80, and 38.50 cm. The lowest values, measuring

26.70, 30.70, and 33.20 cm, were noted when 60% of the available water was drained, both in treatments without additives and with the sequential addition of 0.001 and 0.002 polymers. This may be attributed to sudden changes in soil moisture content, which lead to differences in soil expansion, in addition to the confinement of air within soil pores, which leads to air explosions and the deposition of fine soil particles in the subsoil layer (AL-Sheikhly and AL-Duri, 1998). Furthermore, increasing the depletion percentage to 60% in the presence of gypsum subjects the soil to prolonged drought, thereby increase its bulk density and diminishing both water conductivity and infiltration rates **.**

As the same figures show, the effect of polymer addition levels on cumulative infiltration values. Specifically, at polymer addition ranges of 0.002 and 0.001, there has been a brilliant growth in cumulative infiltration as compared to treatments with none polymer. The maximum recorded values for cumulative infiltration were approximately 42.40, 38.50, and 33.20 cm at the 0.002 addition degree, while values on the 0.001 stage have been round 38.70, 33.80, and 30.70 cm. In contrast, the bottom cumulative infiltration values were found at approximately 34.90, 30.80, and 26.70 cm for remedies with out polymer addition, similar to depletion rates of 40%, 50%, and 60%, respectively. The reason may be attributed to the fact that irrigation using the 0.002 polymer addition level made the soil retain moisture for a longer period, which reduced the effect of the irrigation process on the physical properties of the soil mentioned above, This locating constant with Salih (2023) who reportedThe of superabsorbent polymer its excessive capability in imand prolong soil water preserving capability. Increasing the soil water holding potential because of superabsorbent polymer and ceratophyllum powder addition possibly due to the potential of those elements to enhance the soil physical proprties ,in addition to the role of polymers in improving the soil structure by binding soil particles together, which reduced the dissolution of gypsum in the surface layer and its deposition in the pores of the lower layer. When irrigating treatments without polymer, the dissolution of gypsum particles from the upper layer of the soil and their accumulation in the large pores of the lower layer led to an increase in the bulk density of the soil, which reduced the movement of water to the lower layers**,** It is consistent with what was found by Shihab and Mahdi (2018), as the water conductivity (K) in soil with low gypsum content is low due to the dissolution of a portion of the fine gypsum particles and the transfer of these particles to the bottom, which causes blockage of some soil pores as a result of their sedimentation, which delays the movement of water and reduces the water conductivity.

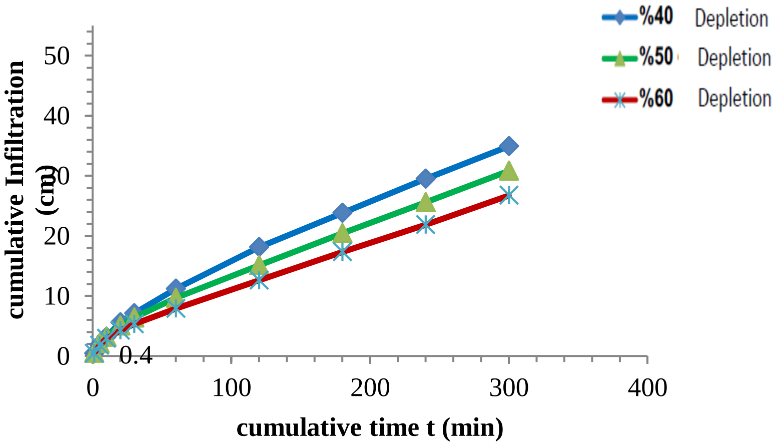

Figure 2. Effect of depletion rates on cumulative soil infiltration for treatment without polymer addition.

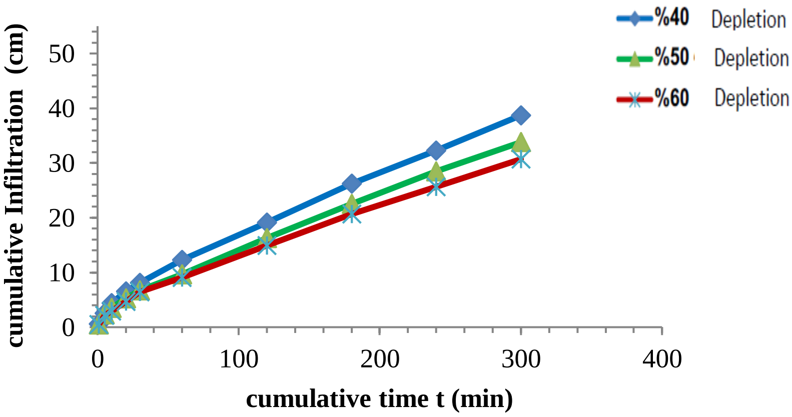

Figure 3. Effect of depletion rates on cumulative soil infiltration for the 0.001polymer addition treatment.

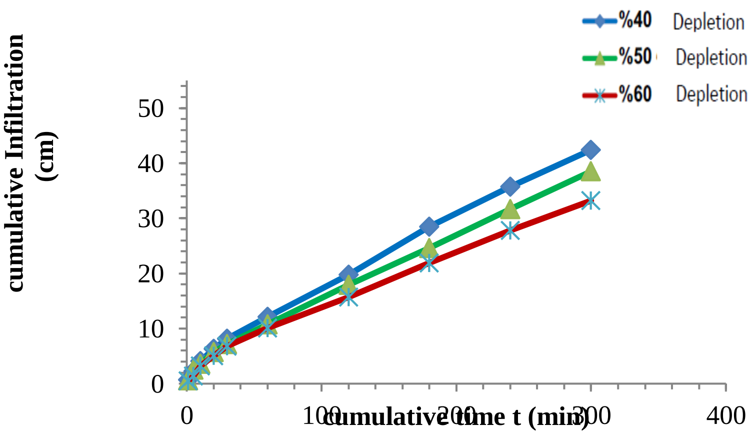

Figure 4. Effect of depletion rates on cumulative soil infiltration for the 0.00 polymer addition treatment.

Table 3 shows the effect of the study treatments on the values of the infiltration rate of the study site soil. We note a decrease in the infiltration rate after planting compared to its value before planting, It decreased by 6.75% when 40% of the available water was exhausted when 0.002 was added, while the decrease rate reached 41.43% when 60% was exhausted for the treatment without addition. This may be due to the washing of gypsum and clay particles from the surface layer of the soil and their deposition in the layers that follow it, which causes the closure of soil pores, especially the large ones, which have a prominent role in the movement of water in saturated conditions. The effect of the successive cycle of wetting and drying also led to as a result of repeated irrigation operations during the season and the accompanying crop service operations to increase the bulk density values compared to their values before planting, which in turn reduced the values of water conductivity and the basic filtration rate. Hydraulic properties of soils are predicted to vary over time at some point of a cropping cycle, mainly soon after tillage, Consistent with the findings of Maba (1986), soil Hydraulic conductivity close to saturation became the maximum sensitive degree of temporal adjustments of hydraulic proprtise, decreasing 100-fold with wetting and drying after tillage. In addition, the infiltration measurements were carried out in field conditions before harvesting the crop in order not to disturb the soil on the terrace. Therefore, the presence of potato tubers in the soil was one of the reasons for obstructing the downward movement of water, which reduced the cumulative infiltration values and the infiltration rate. The infiltration rate values varied based on the study treatment. The maximum infiltration rates recorded were 8.07, 8.56, and 9.25 cm h^{-1} when 40% of the available water was depleted.

In contrast, the minimum rates were 5.81, 6.81, and 7.20 cm $hour^{-1}$ when 60% of the available water was used. Additionally, when 50% of the available water was drained, the infiltration rates measured were 6.90, 7.37, and 8.20 cm h^{-1} at levels of 0.00, 0.001, and 0.002, respectively. These variations in infiltration rates can be linked to the enhanced physical properties of the soil associated with irrigation coefficients at 40% and 50% drainage, as opposed to the 60% drainage treatment. The increase in bulk density and the reduction in saturated water conductivity contributed to the Intercept the downward movement of water, This result is consistent with the findings of Dec et al. (2008) that growing bulk density not most effective results in changes in pore volume distribution, however also affects the soil's shrinkage capacity and water conductivity.

The table also show how Different levels of polymer addition influence the infiltration rate. From this, it is clear that the 0.002 addition treatment is superior, followed by the 0.001 addition treatment, over the treatment without the addition in giving the best filtration values, as the highest values of the characteristic reached 9.25, 8.20, and 7.20 cm h^{-1} for treatments at the 0.002 addition level at depletion rates of 40, 50, and 60% of the ready water, respectively. In comparison, the 0.001 addition level produced rates of 8.65, 7.37, and 6.81 cm h^{-1}, while the non-addition treatment resulted in lower rates of 8.07, 6.90, and 5.81 cm h^{-1} for the same percentages. The observed decrease in infiltration rates can be attributed to the same factors previously discussed.

Table (3): The effect of study processing to the Infiltration rate

Addition procedure	Processing	Main equation for Infiltration	Connection factor R^2	Infiltration rate (i) Cm h^{-1}	Decreasing percentage compared with before agriculture	Infiltration rate before agriculture Cm h^{-1}
0 %	Depletion 40%	$I = 0.0979\ t^{0.5} + 0.1318\ t$	0.9941	8.07	18.64	9.92
	Depletion 50%	$I = 0.0893\ t^{0.5} + 0.1125\ t$	0.9940	6.90	30.44	
	Depletion 60%	$I = 0.0754\ t^{0.5} + 0.0947\ t$	0.9938	5.81	41.43	
0.001	Depletion 40%	$I = 0.1393\ t^{0.5} + 0.1402\ t$	0.9937	8.65	12.80	
	Depletion 50%	$I = 0.0998\ t^{0.5} + 0.1201\ t$	0.9936	7.37	25.70	
	Depletion 60%	$I = 0.0974\ t^{0.5} + 0.1107\ t$	0.9943	6.81	31.35	
0.002	Depletion 40%	$I=0.1336t^{0.5}+0.1504t$	0.9982	9.25	6.75	
	Depletion 50%	$I = 0.1220\ t^{0.5} + 0.1333\ t$	0.9954	8.20	17.33	
	Depletion 60%	$I=0.1015t^{0.5}+0.1172t$	0.9946	7.20	27.41	

CONCLUSION

This study led us to the conclusion that the infiltration rate was low at the end of the season across all processes when compared to the pre-agriculture value. The highest infiltration rate was observed at 40% depletion with an addition of 0.002, while the lowest rate occurred at 60% depletion without any addition. Additionally, the highest coefficient of determination (R^2) between cumulative infiltration and time was recorded at 40% depletion with the addition of 0.002, whereas the lowest value was noted at 60% depletion without any addition**.**

CONFLICT OF INTEREST

The authors report no conflicts of interest related to this manuscript.

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