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ORIGINAL ARTICLE

Evaluation of dripper clogging using magnetic water in drip irrigation

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Abstract

This study was performed to investigate the uniformity of distribution of water and discharge variations in drip irrigation using magnetic water. Magnetic water was achieved by transition of water using a robust permanent magnet connected to a feed pipeline. Two main factors including magnetic and non-magnetic water and three sub-factor of salt concentration including well water, addition of 150 and 300 mg L^{-1} calcium carbonate to irrigation water with three replications were applied. The result of magnetic water on average dripper discharge was significant at ($P \leq 0.05$). At the final irrigation, the average dripper discharge and distribution uniformity were higher for the magnetic water compared to the non-magnetic water. The magnetic water showed a significant effect ($P \leq 0.01$) on distribution uniformity of drippers. At the first irrigation, the water distribution uniformity was almost the same for both the magnetic water and the non-magnetic water. The use of magnetic water for drip irrigation is recommended to achieve higher uniformity.

Keywords Calcium carbonate · Discharge · Distribution uniformity · Dripper clogging · Agricultural

Introduction

Due to the shortage of water resources, the use of available water and use of unusual water is the main objective in agriculture. Increasing population, higher profitable activity and upgraded standards have led to an increase in wars over the freshwater resources. Therefore, it needs to provide additional land for farming to increase food production in order to support the acceleration of population growth to use all sources of low-quality water. Application of saline water with high salinity is an increasing problem in agriculture. In such situation, drip irrigation systems require continuum maintenance. The most important problem and concern dealing with these systems is dripper clogging that inversely affects the uniformity of distribution of water.

Drip irrigation involves small drippers either located on the soil, with water discharge at a well-ordered rate (Elmaloglou and Diamantopoulos 2007; Elmaloglou and Malamos 2006; Wang et al. 2006). Low water request by root of plants preserves an appropriate equilibrium of water and air in soil. Plants grow well under favorable water–air equilibrium and even soil moisture (Cook et al. 2003). Melo et al. (2008) investigated the effects of magnesium and calcium carbonates on dripper clogging and water uniformity distribution in drip irrigation. They showed that the dripper clogging reduced the water uniformity distribution and increased the variation coefficient of drippers. Han et al. (2017) investigated the lateral flushing on the dripper clogging and showed that the coefficient of uniformity of drippers was increased from 11.6 to 67.4% compared with non-flushed treatment.

Limited or comprehensive dripper clogging causes lower water application uniformity and therefore declines crop production and irrigation efficiency (Nakayama and Bucks 1991). Bucks et al. (1982) classified the clogging hazard into three classes of chemical, physical and biological clogging. Chemical blockage is provided to

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sedimentation of calcium and carbonate that is common in arid provinces with waters rich in calcium and bicarbonates. Chemical clogging through salt precipitation is identical hard to be controlled.

Many experimental researches were performed on amendment of calcium carbonate precipitation by magnet device. To adjust water, magnet device can be used (Maheshwari and Grewal 2009; Kney and Parsons 2006).

The variations affected by the magnetic impact depend on several parameters, including power of magnetic field, path of magnetic field, time of magnetic contact, solution discharge and pH (Baker and Judd 1996; Chibowski et al. 2003; Gabrielli 2001; Marcus 1994; Parsons et al. 1997). Ghauri and Ansari (2006) stated that weak magnetic field caused increasing of water viscosity, which was followed by the robust hydrogen bonds under magnet field. Bogatin et al. (1999) showed that quality of irrigation water was improved with magnetic water.

Lundager Madsen (2004) stated that the magnetic field is able to vary the direction of proton spin and to interrupt dehydration occurrences by impeding the transmission of proton to the water bit (Parsons et al. 1997). Busch and Busch (1997) indicated that magneto hydrodynamic effects perhaps be answerable for statements that magnet devices are occasionally active for sediment control in water-using systems. Aali et al. (2009) investigated the dripper clogging by effect of acidification and magnetized water and showed that the dripper indexes such as U_c and Eu in acidification treatment were better than magnetized water. Sahin et al. (2012) evaluated the dripper clogging with magnetized saline water. They found that drippers discharge with magnetized water were higher than non-magnetized water. Shaker et al. (2014) stated that drippers discharge in magnetized water and non-magnetized water treatments were 3.75 and 3.46 L h^{-1}, respectively.

The magnetic water had been investigated by many researches. There is little training about the investigation of magnetic water on water uniformity distribution in drip irrigation. The aim of this research was to study the effects of magnetic saline water on uniformity of distribution of water and variations of dripper discharge in drip irrigation.

Materials and methods

In this research, two subunits were applied and subunits had 9 laterals with length of 40 m, spaced 1.5 m apart. All pipes were polyethylene. Drippers, set 1 m apart. The in-line, long-path, drippers with a discharge of 4 L h^{-1}, were used. Totally 15 irrigations (IN: irrigation number) with intervals of 7 days were applied in Shiraz during the summer 2017. The average temperature was 30 °C. Irrigation was done for 4 h. The schematic structure of irrigation treatment that was used in the field is presented in Fig. 1.

Two main treatments consist of non-magnetic irrigation (W_1) and magnetic irrigation water (W_2), and three subtreatments of salt concentration including control 0.0 mg L^{-1} (S_1), 150 mg L^{-1} (S_2) and 300 mg L^{-1} calcium carbonate (S_3) were used. The following notations were used for the measurements: T_1, T_2, T_3, T_4 and T_5 are for first irrigation, fourth irrigation, eighth irrigation, twelfth irrigation and fifteenth irrigation, respectively. Also, $L_{1,}$ L_2 and L_3 are the drippers located at the start of lateral, the mid of lateral and the termination of lateral, respectively. The dripper discharge was measured by the volumetric method by separating the capacity of collected water under the dripper to the irrigation time

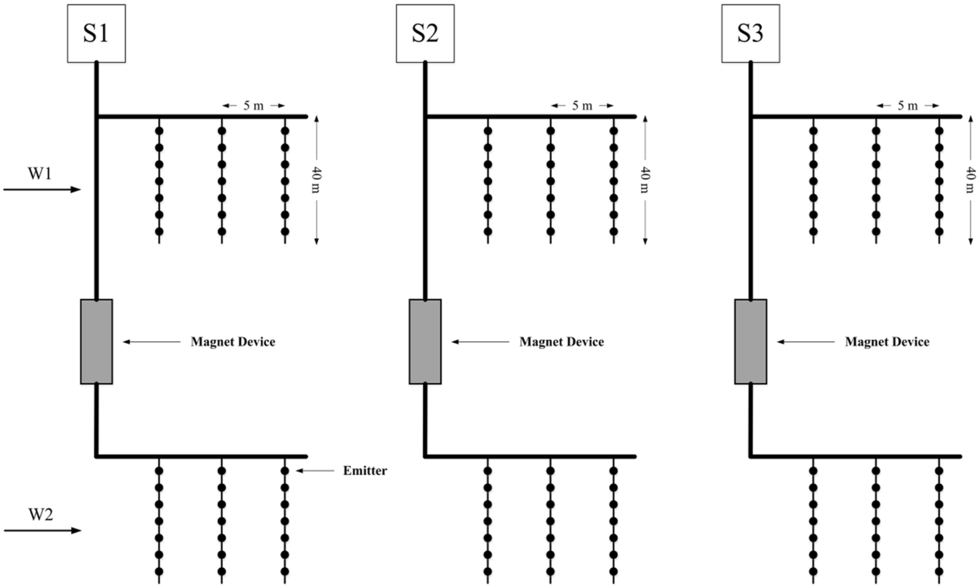

Fig. 1 The schematic of experimental system including the magnetic and non-magnetic sub-systems

of three hours. The Langelier saturation index (LSI) was measured for all treatments to help in prediction of calcium carbonate precipitation. The water distribution uniformity (D_u), emission uniformity (Eu), the Christiansen's coefficients of uniformity (U_c), dripper discharge average (q_a) and the dripper discharge variations (q_{var}) were determined using the equations given by Merriam and Keller (1978). Table 1 shows the mean values of irrigation water characteristics for dissimilar treatments.

Magnetic water was achieved by transition of water using a robust permanent magnet connected to a feed pipeline (Fig. 1).

The permanent magnets (ceramic magnets) with the trade name of Saba Poul (Sabaparsian, Tehran, Iran) were installed around the sub-main pipe before the water enters to the laterals. In the second method, the power requirement was 0.3 Tesla. The south and north poles were located on the top and the down of the pipe, respectively. The procedure of the north and the south poles and path of the formed magnet field are presented in Fig. 2 (Grewal and Maheshwari 2011).

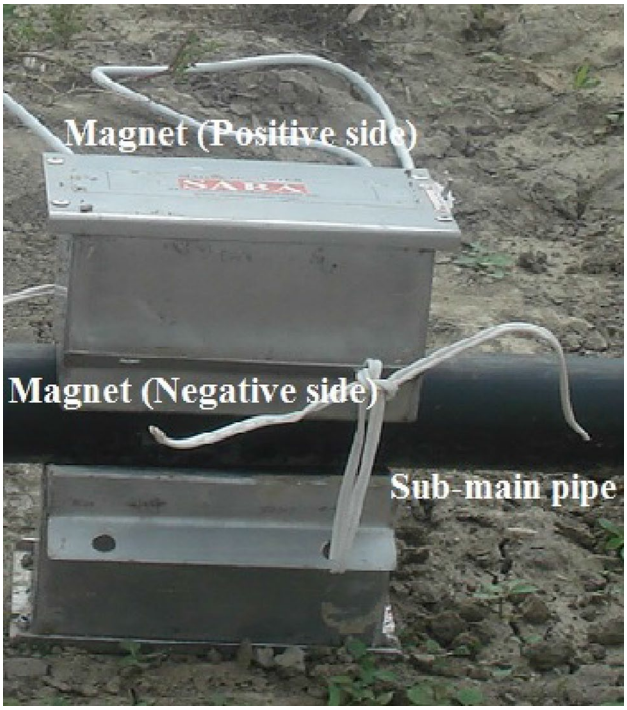

Fig. 2 Magnetic device with two permanent magnets showing their north and south poles

Results and discussion

The result of magnetic water on the electrical conductivity (EC) and LSI of irrigation water was significant ($P \leq 0.05$) (Table 2). The effects of water salinity and time of sampling on EC of irrigation water were significant ($P \leq 0.01$). The interactive effect of magnetic water with time of sampling on the EC of water was significant ($P \leq 0.01$). Similar results were achieved for the interactive effect of water salinity with time of sampling on the EC of water. The highest EC belonged to the water salinity of 300 mg L^{-1} calcium carbonate treatment (Table 3). The mean EC of the magnetic water was more than the non-magnetic water, and the difference was significant at the 5% level (Table 3). The mean LSI of the magnetic water was less than the non-magnetic water, and the difference was significant at the 5% level (Table 3). Magnetic water resulted in less salts precipitate in pipe and higher irrigation water salts which cause higher water salinity. When the water passes from the magnet field its arrangement and some physical features will change (Higashitani et al. 1993). When the carbonate and calcium ions come into the area that is swayed by the magnets, they are pushed in opposed ways, due to their opposed charges. As all of the calcium ions were pushed in one path and all of the carbonate anions were pushed in the opposed direction, they have a tendency to collide. When these impacts occur, the ions stick together starting a solid system of calcium carbonate that was called aragonite. As these tiny crystals are enforced to form while moving in the water, they do not have chance to attach themselves to the pipelines. Therefore, the salts do not residue in the pipelines and cause higher EC.

By using magnetic water, the crystal growth accelerate reduced (Barrett and Parsons 1998; Higashitani et al. 1993). The change of scale can be a product from the special development of the aragonite polymorph (Knez and Pohar 2005; Kobe et al. 2001), instead of calcite. Aragonite, which may be a product from the change of metastable vaterite nuclei, exhibits specific needle form morphology with a fair adhesion to the substrate of the pipe (Fathi et al. 2006; Gabrielli et al. 1999).

With magnetic water, the contact angles are extenuated due to the increase of polarizing effect and the changes in

Table 1 The chemical characteristics of irrigation water for different treatments

Treatments	EC (dS/m)	pH	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	HCO_3 (meq/l)	Cl (meq/l)	SO_4 (meq/l)
S_1	0.58	7.6	2.92	2.11	1.42	3.13	1.26	2.11
S_2	0.73	7.7	3.21	2.35	1.51	3.51	1.31	2.25
S_3	1.01	7.8	3.74	2.59	1.58	4.27	1.38	2.32

Table 2 Analysis of variance for the measured parameters of irrigation treatments

Parameter	Degrees of freedom	Mean squares								
		EC	pH	Ca	Mg	Na	Cl	HCO_3	SO_4	LSI
W	1	0.066^{*}	0.032^{ns}	0.026^{ns}	0.017^{ns}	0.041^{ns}	0.015^{ns}	0.039^{ns}	0.009^{ns}	0.072^{*}
Error	4	0.016	0.012	0.224	0.216	0.104	0.073	0.133	0.206	0.101
S	2	3.54^{**}	0.422^{ns}	47.55^{**}	0.037^{ns}	0.059^{ns}	0.038^{ns}	34.32^{**}	0.033^{ns}	3.82^{**}
$W\times S$	2	0.009^{ns}	0.007^{ns}	0.028^{ns}	0.010^{ns}	0.014^{ns}	0.008^{ns}	0.043^{ns}	0.025^{ns}	0.35^{*}
Error	8	0.022	0.011	0.357	0.064	0.053	0.039	0.198	0.051	0.072
L	2	0.007^{ns}	0.004^{ns}	0.073^{**}	0.044^{*}	0.032^{*}	0.023^{ns}	0.061^{**}	0.006^{ns}	0.009^{ns}
$W\times L$	2	0.006^{ns}	0.005^{ns}	0.009^{ns}	0.031^{ns}	0.0011^{ns}	0.021^{ns}	0.018^{ns}	0.007^{ns}	0.014^{ns}
$S\times L$	4	0.004^{ns}	0.005^{ns}	0.016^{ns}	0.003^{ns}	0.010^{ns}	0.018^{ns}	0.009^{ns}	0.013^{ns}	0.017^{ns}
$S\times W\times L$	4	0.003^{ns}	0.007^{ns}	0.008^{ns}	0.011^{ns}	0.013^{ns}	0.029^{ns}	0.016^{ns}	0.012^{ns}	0.009^{ns}
Error	24	0.003	0.001	0.011	0.014	0.015	0.023	0.020	0.012	0.011
T	2	0.128^{**}	0.014^{ns}	3.94^{**}	0.769^{**}	0.342^{*}	0.039^{ns}	2.83^{**}	0.317^{**}	0.016^{ns}
$W\times T$	2	0.018^{**}	0.006^{ns}	0.068^{**}	0.051^{*}	0.011^{ns}	0.013^{ns}	0.071^{**}	0.043^{*}	0.009^{ns}
$S\times T$	4	0.023^{**}	0.007^{ns}	0.244^{**}	0.032^{ns}	0.026^{ns}	0.008^{ns}	0.030^{*}	0.033^{*}	0.01^{ns}
$S\times W\times T$	4	0.010^{ns}	0.007^{ns}	0.014^{ns}	0.012^{ns}	0.015^{ns}	0.006^{ns}	0.022^{ns}	0.021^{ns}	0.013^{ns}
$T\times L$	4	0.009^{ns}	0.005^{ns}	0.004^{ns}	0.027^{ns}	0.011^{ns}	0.019^{ns}	0.025^{ns}	0.016^{ns}	0.017^{ns}
$W\times T\times L$	4	0.012^{ns}	0.011^{ns}	0.018^{ns}	0.016^{ns}	0.013^{ns}	0.022^{ns}	0.019^{ns}	0.014^{ns}	0.021^{ns}
$S\times T\times L$	8	0.011^{ns}	0.0015^{ns}	0.013^{ns}	0.024^{ns}	0.017^{ns}	0.015^{ns}	0.026^{ns}	0.009^{ns}	0.038^{ns}
$S\times W\times T\times L$	9	0.003^{ns}	0.007^{ns}	0.014^{ns}	0.016^{ns}	0.013^{ns}	0.023^{ns}	0.019^{ns}	0.012^{ns}	0.009^{ns}
Error	72	0.005	0.004	0.017	0.025	0.029	0.031	0.019	0.031	0.032

*,** and ns, represent significant at 5% level, significant at 1% level and nonsignificant, respectively. *W*, *S*, *L* and *T* represent type of irrigation water, irrigation water salinity, dripper location, and time of sampling, respectively

Table 3 The comparison of the mean values for the measured chemical parameters of irrigation water

	Treatment	EC	pH	Ca	Mg	Na	Cl	HCO_3	SO_4	LSI
W	W_1	0.75^{b}	7.63^{a}	3.98^{a}	2.12^{a}	1.60^{a}	1.34^{a}	3.79^{a}	2.17^{a}	2.1^{a}
	W_2	0.88^{a}	7.60^{a}	3.89^{a}	2.14^{a}	1.55^{a}	1.36^{a}	3.71^{a}	2.19^{a}	0.3_{b}
S	S_1	0.61^{c}	7.60^{a}	3.01^{c}	2.11^{a}	1.56^{a}	1.34^{a}	3.10^{c}	2.14^{a}	0.2^{c}
	S_2	0.79^{b}	7.66^{a}	3.85^{b}	2.10^{a}	1.62^{a}	1.38^{a}	3.69^{b}	2.12^{a}	0.9^{b}
	S_3	1.04^{a}	7.78^{a}	4.97^{a}	2.13^{a}	1.64^{a}	1.39^{a}	4.44^{a}	2.19^{a}	2.5^{a}
L	L_1	0.81^{a}	7.69^{a}	4.00^{a}	2.15^{a}	1.62^{a}	1.38^{a}	3.80^{a}	2.20^{a}	1.6^{a}
	L_2	0.81^{a}	7.68^{a}	3.94^{b}	2.14^{a}	1.61^{a}	1.35^{a}	3.78^{a}	2.19^{ab}	1.7^{a}
	L_3	0.79^{a}	7.69^{a}	3.93^{b}	2.09^{b}	1.56^{b}	1.34^{a}	3.74^{b}	2.17^{b}	1.9^{a}
T	T_1	0.85^{a}	7.70^{a}	4.16^{a}	2.22^{a}	1.69^{a}	1.40^{a}	3.95^{a}	2.23^{a}	1.5^{b}
	T_3	0.82^{b}	7.70^{a}	3.98^{b}	2.15^{b}	1.63^{b}	1.37^{ab}	3.79^{b}	2.18^{b}	1.7^{b}
	T_5	0.77^{c}	7.68^{a}	3.71^{c}	2.03^{c}	1.55^{c}	1.36^{b}	3.60^{c}	2.10^{c}	2.0^{a}

Each value in the table is an average of three replications

distribution and clustering construction of water particles after magnetization. The extenuation of contact angles of magnetic water leads to increase the hydrophobic materials and decrease its surface tension force relative to that of well water, and thus its hydrophobicity decreases. As a result, it causes growth the solubility rule (Pang and Deng 2008). Bo et al. (2016) stated that dripper clogging control policy could be recognized according to suspended particles components in the same reclaimed water.

Table 4 shows the interaction effects of water irrigation and salinity water treatments on chemical parameters of irrigation water. The difference of LSI index between S_1, S_2 and S_3 under non-magnetic water and S_1, S_2 and S_3 under magnetic water was significant at 5 percent probability level. But the difference of other chemical parameters of irrigation water between S_1, S_2 and S_3 under non-magnetic water and S_1, S_2 and S_3 under magnetic water was not significant (Table 4).

Table 4 The interaction effects of water irrigation and salinity water treatments on chemical parameters of irrigation water

	EC		pH		Ca		Mg		Na		Cl		HCO_3		SO_4		LSI	
	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2
S_1	0.55^a	0.75^a	7.62^a	7.61^a	3.1^a	2.95^a	2.07^a	2.15^a	1.61^a	1.51^a	1.29^a	1.39^a	3.28^a	2.92^a	2.11^a	2.17^a	0.25^e	0.15^e
S_2	0.68^a	0.90^a	7.63^a	7.69^a	4^a	3.7^a	2.05^a	2.15^a	1.69^a	1.55^a	1.30^a	1.46^a	3.75^a	3.63^a	2.08^a	2.16^a	1.02^c	0.78^d
S_3	0.93^a	1.15^a	7.80^a	7.50^a	5.05^a	4.89^a	2.09^a	2.17^a	1.70^a	1.58^a	1.32^a	1.46^a	4.56^a	4.32^a	2.10^a	2.28^a	3.02^a	1.98^b

In each column and for each treatment, the values followed by at least one common character are not statistically different at 0.05 probability level

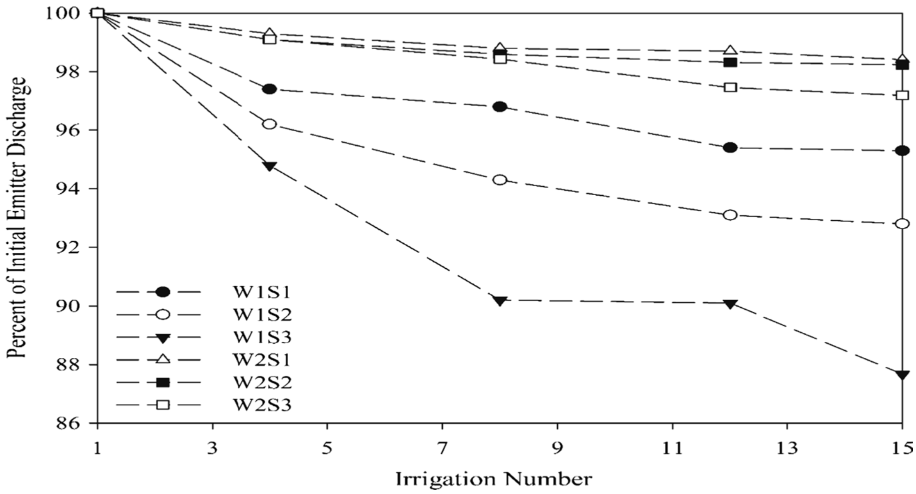

Fig. 3 Variations of dripper discharge during the experiment period

Figure 3 shows the comparison of changes of dripper discharge average for different treatments during the irrigation period. Our results presented that fewer variations in dripper discharge average occurred with the magnetic water (Fig. 3). At the first irrigation, there was no significant difference between the W_1S_1 and W_2S_1 treatments, but after the final irrigation, the difference between the above two treatments increased. For the W_1S_1 treatment, the reduction in dripper discharge average up to the final irrigation season was 4.7%, while it was 1.59% for the W_2S_1 treatment. This shows that for the magnetic water, there was lower dripper discharge average during the experiment and there were less salt precipitations in the pipelines. For the S_2 and S_3 treatments, the reduction in dripper discharge average was higher during the irrigation term which shows that as the water salinity increases the salt precipitations also increase. For the W_1S_2 treatment, the reduction in dripper discharge average up to the final irrigation was 7.2%, while it was 1.76% for the W_2S_2 treatment. The reduction in dripper discharge average up to the final irrigation for the W_1S_3 treatment was 12.33%, while it was 2.81% for the W_2S_3 treatment. The highest reduction in dripper discharge average belonged to the W_1S_3 treatment and the lowest reduction in dripper discharge average belonged to the W_2S_1 treatment.

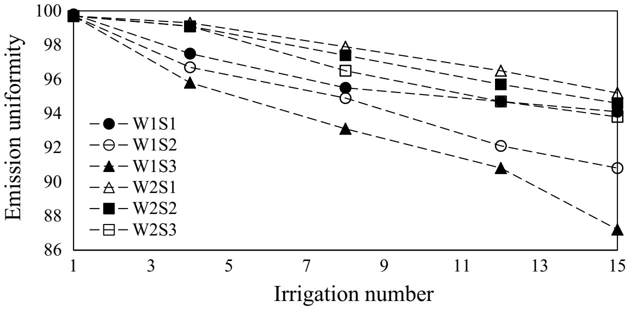

Fig. 4 Variations of emission uniformity during the experiment period

Figures 4, 5 and 6 show the changes of emission uniformity, Christiansen's coefficients of uniformity and distribution uniformity, respectively, for different treatments during the irrigation period. The results presented that fewer variations in dripper occurred with the magnetic water. At the first irrigation, there was no significant difference between the W_1S_1 and W_2S_1 treatments, but after the final irrigation, the difference between the above two treatments increased. For the W_1S_1 treatment, the reduction in emission uniformity up to the final irrigation season was 5.71%, while it was 2.2% for the W_2S_1 treatment. For the W_1S_2 treatment, the reduction

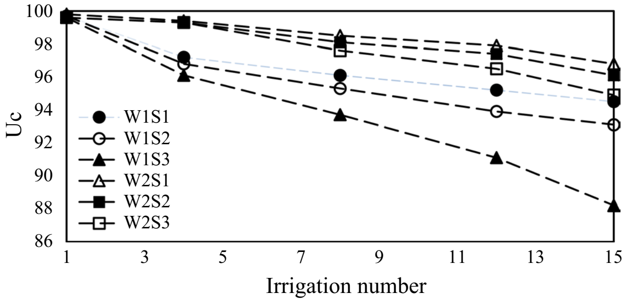

Fig. 5 Variations of Christiansen's coefficients of uniformity during the experiment period

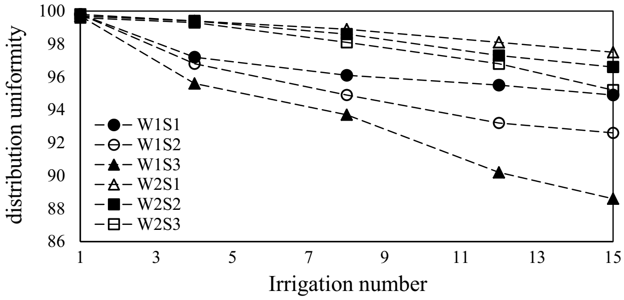

Fig. 6 Variations of distribution uniformity during the experiment period

in emission uniformity up to the final irrigation was 8.92%, while it was 5.11% for the W_2S_2 treatment. The reduction in emission uniformity up to the final irrigation for the W_1S_3 treatment was 12.53%, while it was 5.91% for the W_2S_3 treatment (Fig. 4).

For the W_1S_1 treatment, the reduction in Christiansen's coefficients of uniformity up to the final irrigation season was 5.21%, while it was 3% for the W_2S_1 treatment. This was consistent with Han et al. (2017) findings, whose results concluded that the frequency increased, coefficient of uniformity decreased. For the W_1S_2 treatment, the reduction in Christiansen's coefficients of uniformity up to the final irrigation was 6.62%, while it was 3.51% for the W_2S_2 treatment. The reduction in Christiansen's coefficients of uniformity up to the final irrigation for the W_1S_3 treatment was 11.44%, while it was 4.71% for the W_2S_3 treatment (Fig. 5).

For the W_1S_1 treatment, the reduction in distribution uniformity up to the final irrigation season was 4.9%, while it was 2.2% for the W_2S_1 treatment. For the W_1S_2 treatment, the reduction in distribution uniformity up to the final irrigation was 7.21%, while it was 3.2% for the W_2S_2 treatment. The reduction in distribution uniformity up to the final irrigation for the W_1S_3 treatment was 11.13%, while it was 4.41% for the W_2S_3 treatment (Fig. 6).

At the first irrigation, the dripper discharge average for the magnetic and non-magnetic water was the same, but at the final irrigation, this value for the magnetic water was more than the non-magnetic water which indicates less salt precipitate under magnetized condition. This result is agreement with the findings of Basher (2006).

Analysis of presented variance showed that the result of magnetic water and water salinity on dripper discharge average was significant ($P \leq 0.05$) (Table 5). This table also shows that time of sampling, the interactive of irrigation water type with sampling and the interactive of water salinity with sampling on dripper discharge average were significant ($P \leq 0.01$). The distribution uniformity for the non-magnetic water was less than magnetic water (Table 6). The decrease in distribution uniformity was advanced in higher irrigation water salinities. The highest difference in the reduction in the distribution uniformity between the magnetic water and the non-magnetic water occurred at water salinity of 300 mg L^{-1} calcium carbonate. This shows that the effect of magnetic water becomes higher as the irrigation water salt

Table 5 Analysis of variance for the parameters

Parameter	Degree of freedom	Mean squares				
		q_a	Eu	U_c	D_u	q_{var}
W	1	0.18*	70.11**	14.12**	11.28**	82.14**
Error	4	0.01	1.18	0.53	0.42	1.45
S	2	0.19*	28.10**	10.08**	8.17**	89.41**
$S\times W$	2	0.04^{ns}	15.59**	0.78^{ns}	0.39^{ns}	11.73^{ns}
Error	8	0.02	0.39	0.31	0.44	5.98
T	4	0.46**	152.6**	53.8**	49.14**	413.5**
$W\times T$	4	0.31**	24.37**	12.13**	10.76**	29.62**
$S\times T$	8	0. 27**	11.09**	4.63**	3.95**	15.03**
$S\times W\times T$	8	0.01^{ns}	1.66^{ns}	0.23^{ns}	0.11^{ns}	6.19^{ns}
Error	48	0.01	0.5	0.12	0.08	0.94

*,** and ns, represent significant at 5 percent level, significant at 1 percent level and nonsignificant, respectively. *W* represents type of irrigation water, *S* is irrigation water salinity, and *T* is time of sampling

Table 6 Comparison of means of the parameters

Treatments		q_a	Eu	U_c	D_u	q_{var}
W	W_1	3.78^b	88.43^b	89.06^b	90.24^b	17.85^a
	W_2	3.84^a	92.26^a	94.83^a	94.94^a	15.08^b
S	S_1	3.87^a	92.32^a	94.98^a	95.07^a	14.76^c
	S_2	3.80^{ab}	89.42^b	91.50^b	92.62^b	16.34^b
	S_3	3.76^b	87.29^c	86.86^c	89.08^c	18.30^a
T	T_1	3.98^a	94.31^a	96.05^a	96.13^a	11.24^a
	T_2	3.94^b	93.62^b	94.65^b	94.74^b	12.56^b
	T_3	3.86^c	92.05^c	91.79^c	91.90^c	15.21^c
	T_4	3.77^d	89.63^d	87.57^d	89.71^d	19.22^d
	T_5	3.65^e	87.01^e	85.16^e	87.48^e	24.10^e

Each value in the table is an average of three replications

Table 7 The interaction effects of water irrigation and salinity water treatments on the dripper parameters

	q_a		Eu		U_c		D_u		q_{var}	
	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2
S_1	3.74^a	4^a	90.11^b	94.53^a	93.16^a	96.8^a	94.32^a	95.82^a	16.51^a	13.01^a
S_2	3.69^a	3.91^a	87.51^c	91.33^b	90.21^a	92.79^a	91.07^a	94.17^a	17.72^a	14.96^a
S_3	3.65^a	3.87^a	85.14^d	89.44^c	85.19^a	88.53^a	87.89^a	90.27^a	19.77^a	16.83^a

In each column and for each treatment, the values followed by at least one common character are not statistically different at 0.05 probability level

increases. Similar results were found for other uniformity parameters such as the emission uniformity and the Christiansen's uniformity coefficients of the dripper discharge.

The dripper discharge variations for the magnetic water were lower than the non-magnetic water. The lowest dripper discharge variations belonged to the control treatment. Proceeding through the time, the dripper discharge average decreased. At the first irrigation, the distribution uniformity was almost the same for both the magnetic water and the non-magnetic water. At the final irrigation, the uniformity parameters of magnetic water were higher than non-magnetic water.

Table 7 shows the interaction effects of water irrigation and salinity water treatments on the dripper parameters. The difference of emission uniformity between S_1, S_2 and S_3 under non-magnetic water and S_1, S_2 and S_3 under magnetic water was significant at 5 percent probability level. But the difference of q_a, U_c, D_u and q_{var} between S_1, S_2 and S_3 under non-magnetic water and S_1, S_2 and S_3 under magnetic water was not significant (Table 4).

Conclusions

Magnetic water can improve irrigation performance in drip irrigation. Irrigation using magnetic water compared to the non-magnetic water increased the dripper discharge average which indicates less dripper clogging and high distribution uniformity. The results displayed that the dripper discharge average is influenced by type of irrigation water and water salinity. The magnetic water showed significant influence on average dripper discharge, uniformity of distribution of water, emission uniformity, and Christiansen's uniformity coefficients of the dripper discharge, and the dripper discharge variations. For the non-magnetic water treatments, the average reduction in distribution uniformity up to the final irrigation was 10%, while it was 2% for the magnetic water treatment. Also, the average reduction in distribution uniformity up to the final irrigation for the non-magnetic water treatment was 6%, while it was 2% for the magnetic water treatment. These results can be useful in solving the problems of dripper clogging with applied of saline water.

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