

MAGNETIC "SALT"/ALKALI METAL DISPERSION

A Study of

The Effect of Irrigation with Magnetically Treated Water on the Translocation of Minerals in the Soil

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agnetically Treated Water (MTW) is water passed through a magnetic field before being used. Applications of MTW are abundant in industry, where it is used to prevent scaling on the inner walls of pipes conveying fluids, especially water. In recent years scientists investigating the subject have concluded that the magnetic field interacts with the surface charged of particles in the fluid solutions affecting the crystallization and precipitation of the solids in them. These processes are of significant effect on the translocation of minerals in irrigated soil.

In this work the contents of K, N, P, Na, and Ca+Mg as well as the total mineral content in MTW are irrigated with ordinary water. The soil was sampled at three different locations at three different distances from the dripper line, representing three different leaching states of the soil. Differences in concentrations were found in at least one of the three locations with respect to each mineral and including the total mineral content. Most of the differences appeared in the less leached parts of the soil, in the bed margin. It appears that there is a general tendency of minerals to precipitate out of the solution faster in MTW conditions.

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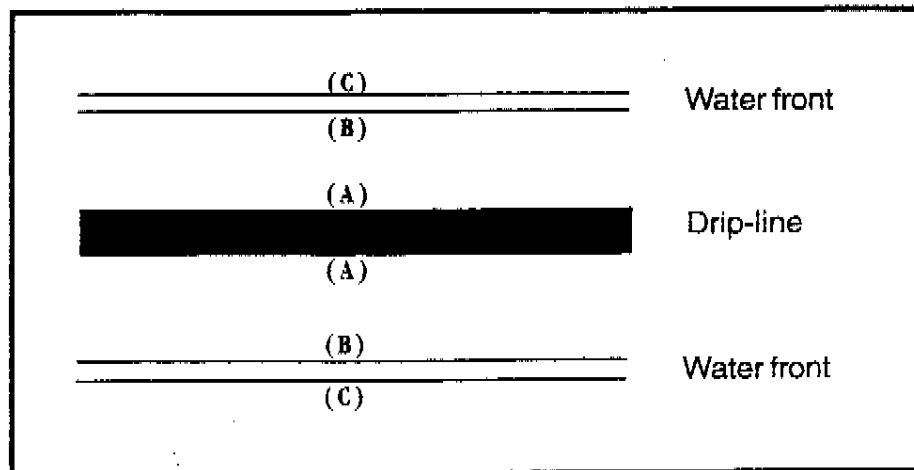
For many years now research has been carried on showing the effects of magnetic fields on growth processes and the development of plant tissues [Tolomei 1893, Ssawastin 1930, Audus 1960, Dubinskaya 1973, Pittman et al. 1979, Dayal & Singh 1986]. Such research as a rule involved the exposure of an entire plant to an external magnetic field [Sheppard & Eizenbud 1977, McLeod et al. 1992], induction of a magnetic field in the soil surrounding the plant's root system [Vodianitskii 1974, Vodianitskii & Lunkova 1976], or irrigation with water that had undergone magnetic treatment before being introduced into the soil [Volkonskii et al. 1978, Lin & Yotvat 1990, Moran et al. 1992, 1993].

Magnetically treated water (MTW) is water subjected to treatment in and by a magnetic field. For irrigation purposes this means water that had passed apparatus containing a permanent magnet. The use of MTW is common in various branches of industry as a precaution against the accumulation of scale in the water supply system, in cooling towers, and in thermal and solar heating installations [Lin & Yotvat 1988, 1990].

Much work has been done in this connection, dealing with such minerals as calcium carbonate, phosphorus carbonate, barium sulfate, zinc phosphate, and calcium oxalate. For example, laboratory tests in a certain heating system fed with MTW established that a deposit of 0.1 gr of calcium carbonate had formed, as compared with 40 gr accumulated in a system using untreated water. Tests made in five different humidity maintenance systems showed that the treatment prolonged their service life from 1000-1500 hours to over 2200 hours, the observation being called off after that [Donaldson 1990].

There is another system for magnetic water treatment, which does not involve the use of an external field. Water is made to flow through a maze made of a proprietary alloy apparatus that is called Catalytic Alloy Conditioner. [Institute of Technology; Haifa 32000, Israel. {R}]. Its principles of operation are discussed in [Kim 1987].

In work done in recent years at the laboratory of Professor Donaldson, Department of Chemistry, Brunel University, London, and dealing with the effects of a magnetic field on liquids, the scientists



(Figure 1) Schematic representation of the experimental plot. The sketch shows the locations of the samplings, (A), (B), and (C), distanced 5 cm, 40 cm, and 60 cm, respectively, from the dripper line. The boundary of the "wet spot" (the wetting front) is 50 cm away from the line.

came to the conclusion that the principal activity consists in the interaction between the magnetic field and the surface charges of particles in the liquid. According to these findings the field can react with a wide variety of particles: Ions, polar molecules, ion pairs, free radicals, crystalline crystallization nuclei, and suspensions with a surface charge.

There are two kinds of reaction: (1) Direct reactions with the charged particle and (2) magneto-kinetic modifications (influence of the magnetic field on certain energy levels of the molecule). As a result of these reactions the behavior of the particles changes in the area of crystallization and precipitation of the solutes in the solvent. The changes taking place were measured in a number of respects: The size of the crystallizing particles, their shape, the quantitative relationships between the different crystalline shapes, crystallization processes, the solubility of the mineral, and the rate of precipitation. In all these respects the influence of the magnetic treatment of the liquid was revealed, and as a result of these findings the main research effort is now focused on the study of the modification of the crystallization processes and the various scientific and commercial aspects connected therewith [Donaldson 1990].

The mechanism of MTW activity in the soil is as yet unclear. There is a

possibility that the effect is physical, through a change in the solvent capacity of the water; an increase in that capacity may be the explanation of the differences, detected while examining the soluble fraction of the soil, between ordinary water and MTW. These differences varied between 50% and 300% [Harrary, M. & Lin 1989]. There is a conjecture that the water has a direct effect on physiological processes in the plant cells, and it is possible that the reactions of the plant are of secondary importance, the direct influence being concentrated mainly on the composition or the mineral structure of the soil.

The movement of water during drip irrigation caused a "wet spot" on the soil surface on both sides of the dripper line. The salt concentration in the soil change as a result of the salts' being dissolved and washed away by the irrigation water, the movement of the salts in the soil corresponding to the route of progress of the wetting front of the water. This movement starts at the dripper line, which is situated at the enter of the bed, and ends at the borderline of the wet spot on both sides of the line. The direction of the movement is perpendicular to that of the line. At the end of irrigation the wetting profile in the soil assumes the shape of an onion (the "wetting onion") the salt content of which being so divided that the lowest concentration is found next to the dripper and the high-

st near the borderline of the wet spot [Bresler 1975].

The aim of the present work was to clarify the influence of magnetic water treatment on the movement of the salts in the field drip-irrigated with MTW and to determine if the distribution profile of the minerals dissolved in the MTW-irrigated area differs from that in the control area, which was irrigated with untreated water.

Materials and Methods

Location: The investigation was carried out on an experimental plot of land, which formed part of a field of fall melons grown organically at Kibutz Yotvata. The area had not been worked for three years before the experiment.

Leaching the soil: The melon field containing the experimental plot was regularly irrigated, an evaporation coefficient of 1.0 being taken into account. A dripper line dispensing 2.3 l/hr per dripper and with drippers spaced at intervals of 40 cm was laid along the enter line of each bed in a groove 5-8 cm deep. One week after the start of irrigation the magnetic treatment of the irrigation water was started on the plots assigned to such treatment. The treated and the control beds were adjacent to each other and located in close proximity to the outlet cock.

Magnetically treated water: The magnetic

treatment was administered by passing the irrigation water through a metal pipe containing a magnetic apparatus called "Agrimag" made by "Elir", recommended to operate at a throughput of 0.9 m³/hr. The magnetic treatment apparatus was set up close to the water outlet of the main line.

Fertilization: The experiment was operationally connected with the organic melon plot, and no mineral fertilizer was added. A guano solution of varying concentrations was occasionally applied.

Soil wetness: The "wet spot" - the boundary of the soil wetness as discernible by visual inspection of the soil surface - attained 50 cm on either side of the dripper. Examinations made at two-week intervals established that the amounts of water supplied by the two dripper lines were equal. One week before the end of the experiment the water content of the soil was measured, repeated 4 times, at a distance of 50 cm from the dripper and a depth of 30 cm. The results were not significantly different: 86.5 ± 0.3 % humidity in the MTW plot against 85.8 ± 0.0% in the control plot.

Soil sampling for testing mineral concentration: In drip irrigation the water movement and mineral leaching profile in the soil is in the shape of a half-ellipse or "onion" [Mostaghimi & Mitchell 1974, Kaul & Michael 1975, Bresler 1983]. The salt content of the "wetting onion" is so distrib-

Accordingly, sampling points were set at three distances:

- (A) Inside the "wet spot", close to the dripper line;
- (B) Inside the "wet spot", close to its boundary;
- (C) Outside the "wet spot", but close to its boundary.

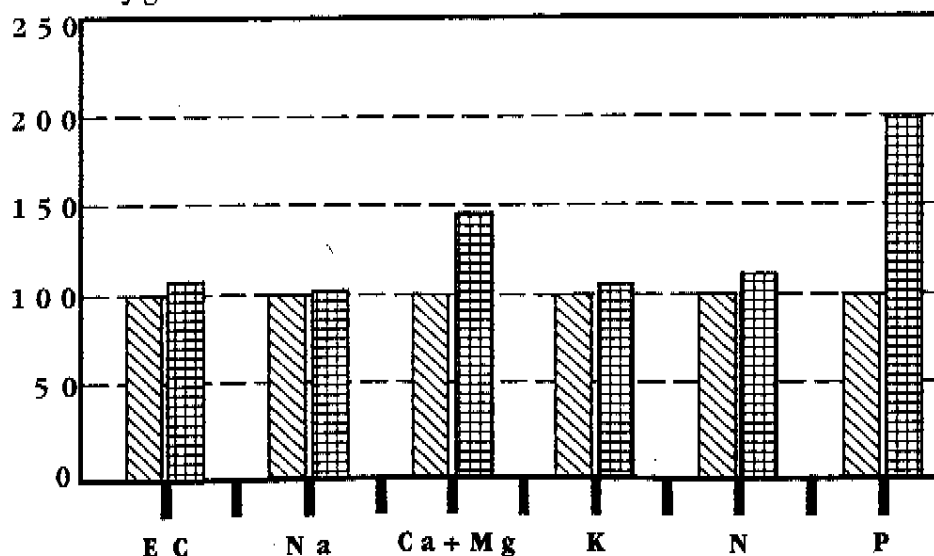
It is important to stress that while point (A) is in the area most highly leached of minerals, points (B) and (C) are in the area where the minerals settle, in other words the area of higher concentration of the leached minerals (Bresler 1975). By means of points (A), (B), and (C) in Figure 1 These two different areas can be defined in terms of the extent of leaching they have undergone:

1. **Area (A-B)** (Between (A) and (B)) was the most highly leached, because the water passed through it and the wetting front moved across it throughout all the irrigation cycles.
2. **Area (B-C)** (Between (B) and (C)) was less leached than the above, because the water passed through it and the wetting front moved across it for only part of the irrigation cycles.

Soil sampling: Soil specimens were taken after 28 days of irrigation with MTW. The sampling, from a depth of 20 cm, was repeated four times at a distance of from 8 m to 10 m from the end of the plot. The specimens, in paper bags, were dried in a ventilated storeroom and then taken to the Field Service Laboratory at Hadera.

Statistics: The confidence level of the differences in the results was examined by the test.

fig. 2 CONCENTRATION NEAR DRIPPER



Concentration of salts in the soil at sampling location (A), the outlet of irrigation water from the dripper (the center of the "wetting onion") according to the data in Table 1, column A (see also Figure 1). No difference was found between the MTW-irrigated plot and control, as regards both overall electric conductivity and the specific concentrations of N, K, and Na. Only the results with respect to P and Ca+Mg differ in this connection. See text.

Results

The differences in salt concentrations between the MTW-irrigated and the control plots: The boundary of the "wet spot" was 50 cm distant from the dripper line. Soil samples were taken at points (A), (B), and (C) after 28 days of irrigation in order to measure the overall concentration of solutes and the concentrations of the salts of K, P, N, Na, and Ca-Mg at different distances from the dripper line (see Figure 1 and the Section, "Materials and Methods"). The differences observed between the MTW-irrigated and the control beds reached, at certain points, a confidence level of between 90% and 99% (Table 1).

Concentrations next to the dripper line: The mineral concentrations in the soil close to the dripper line as listed in Table

1 are illustrated in Figure 2. Near the line the soil is leached to a higher degree than elsewhere within the confines of the "wetting onion" [Bresler 1975], and clear differences in salt concentrations between the MTW-irrigated and the control beds were found only with respect to the divalent ions and phosphorus (Figure 2, Table 1).

Translocation of salts in the two different leaching areas:

(For definitions of the zones see the Section, "Materials and Methods".

1. **The completely leached zone,** between points (A) and (B), which define the A-B zone. A fall in concentrations typical of the "wetting onion" [Bresler 1975] is observed, with no significant difference between the MTW-irrigated and the control

beds (Table 1).

2. **The partially leached zone,** between points (B) and (C), which define the B-C zone. The translocation of salts in the less leached zone is shown in Figure 3, prepared on the strength of the data in Table 1.

As distinct from the A-B zones, there are differences between the B-C zones of the two plots: in the one irrigated with MTW a common and characteristic profile indicates a drip in salt concentrations from Point B to Point C (Figure 3b), whereas in the control beds there is no common and characteristic profile (with regard to some of the salts there is a tendency to a rise in salt concentrations from Point B to Point C (Figure 3a).

DISTANCE FROM DRIPPER-LINE: TREATMENT:		(A) 5cm		(B) 40cm		(C) 60cm	
		Control	MTW	Control	MTW	Control	MTW
EC (mmho/cm)		4.3	4.7	9.9	10.9a	10.1	8.3c
		0.5	0.5	0.3	0.3	1.8	1.0
Na (Meq/l)		16.6	16.9	45.0	53.5a	49.5	39.8
		1.9	1.9	3.0	2.1	12.8	7.3
Ca+Mg (Meq/l)		39.6	56.4a	73.0	74.4	92.2	62.7b
		6.8	6.3	14.9	19.1	12.6	14.2
K (Meq/l)		1.3	1.3	12.0	9.7	5.6	8.4c
		0.1	0.1	0.5	1.9	0.8	2.5
N [NO3] (p.p.m.)		3.6	4.0	8.4	15.3b	19.5	13.8
		1.1	0.5	1.3	5.2	6.5	7.6
P [Olsen] (p.p.m.)		118.9	239.0a	123.3	195.8b	71.1	117.3
		13.9	17.4	51.5	28.4	29.0	26.5

Table 1: Electric Conductance and Mineral Concentrations in the Soil Solution at Different Distances from the Dripper Line (Average and standard deviation of 4 repeats of each test)

a -	$P < 0.01$
b -	$0.01 < P < 0.05$
c -	$0.05 < P < 0.10$

Discussion

The aim of this work was to elucidate the influence of magnetic water treatment on the movement of salts in the soil. During drip irrigation the movement of the water perpendicularly to the dripper line causes a "wet spot" on the soil surface on both sides of the line [Bresler 1975]. Acting on the assumption that the magnetic field affects the particles in the solution [Donaldson 1990], the possibility was investigated that the field alters the interaction of the solutes with the water and the

soil, and as a result the concentrations of the minerals in the soil of the plot irrigated with magnetically treated water (MTW) at given distances from the dripper line differ from those in the control plot.

The differences in the salt concentrations between the MTW-irrigated plot and control.

The examination of the overall solute concentrations and the concentrations of specific salts (potassium, phosphorus, nitrogen, sodium, and calcium + magnesium) produced results that support the basic assumption that irrigation with MTW affects

the movement of salts in the soil: With respect to all the salts and at different distances from the dripper line differences were found between the MTW-irrigated and the control plot at confidence levels of between 90% and 99% (Table 1).

The influence of MTW-irrigation on the movement of salts in the soil in Area B-C.

In Area B-C the analysis of the movement of salts in the soil within the limits of the "wet spot" showed clear differences between the MTW-treated plot and control

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from the point inside the "wet spot" to the point outside it (Figure 3b), whereas in the control plot there is no such common and characteristic profile. Moreover, an opposite tendency is discernible in some of the salts - viz. a tendency to a rise in salt concentration from the point within to that outside the "wet spot" (Figure 3a).

The fact that the differences were found in the B-C area (Figure 1, the area subjected to partial leaching), and not in the completely leached Area A-B, (Figure 3) can be explained by the latter area's salt leaching having reached the highest, final stage, both on the MTW-irrigated plot and on the control. At that stage it is already difficult to detect any differences.

Calcium and magnesium salts. Close to

the dripper line (at point A) there is a noticeably higher concentration of the divalent ions, (Ca+Mg), in the plots irrigated with MTW as compared with the control plots (Figure 2). This result fits in well with the known phenomenon of the effect of MTW on the prevention of calcium salt accumulation ("scale") in the pipes of industrial systems, explained by the fact that the passage of water through magnetic and similar apparatus causes calcium salts to create, under the influence of the said treatment, relatively large crystals which sink easily, compared with the slow crystallization and precipitation of these salts in untreated water [Kim 1987].

The changes in phosphorus concentrations in the soil. Already in close proximity of the dripper line the great difference

in the concentrations of this mineral in the MTW-irrigated and the control plots is evident (Table 1, Figure 2). The data point to the particularly high solubility of phosphate under the influence of the magnetic treatment, conforming to the findings of work carried out in connection with zinc phosphate at the laboratory of Prof. Donaldson of Brunel University: Experiments run in the laboratory, and data supplied by industry, m showed the clear influence of the magnetic treatment on the increase in solubility (or in the level of concentration in supersaturation) of zinc phosphate. As regards calcium phosphate they show an increase of 50% in the dissolution capacity after 24 hours of magnetic treatment and a fivefold increase after 120 hours [Donaldson 1990].

fig. 3a LEACH - (B-C) ZONE, CONTROL

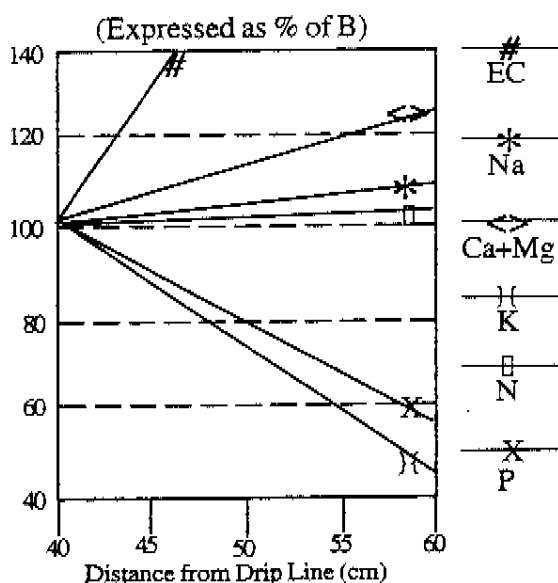


fig. 3b LEACH - (B-C) ZONE, MTW

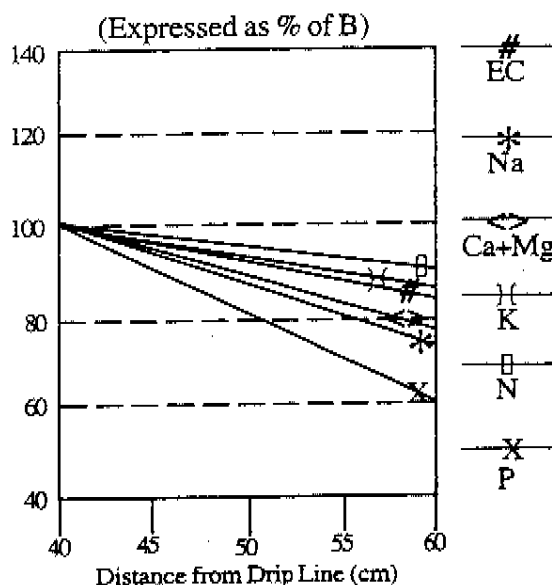


FIGURE 3: The change in salt concentrations in the soil in the partial-leaching area (B-C) at different distances from the dripper (see Figure 1). The results are quoted as percentages of the concentration at Point (B).

3a: Untreated water
3b: Magnetically treated water

Conclusions

The results of this work confirm the assumption that as a result of the influence of a magnetic field on solutes [Donaldson 1990] the interaction between soil particles and salts dissolved in ordinary water does not resemble the interaction between the soil particles and the salts dissolved in magnetically treated water (MTW). It appears that, generally speaking, magnetic treatment of the water slows down the movement of the minerals, perhaps due to the effect of MTW—speeding up crystallization and precipitation processes of the solute minerals. That effect is clearly discernible when flushing is not yet complete (Figure 3).

What is still required is an investigation of the kinetics of the mineral movement in the soil during irrigation in order to study the dependence of the distribution profile of different minerals on the quantity of water introduced into the soil. It is worthwhile to clarify the specific effect of irrigation with MTW on each mineral separately. The results obtained in the present work with respect to phosphorus, and other works showing the effect of the magnetic field on the solubility of phosphorus salts [Donaldson 1990], are an indication of the interest that attaches to the study of phosphate behavior in MTW-irrigated soil.

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